AD NUMBER
AD396801
CLASSIFICATION CHANGES
TO: unclassified
FROM: restricted
LIMITATION CHANGES
TO: Approved for public release, distribution unlimited
FROM: Distribution authorized to U.S. Gov't. agencies and their contractors; Foreign Government Information; APR 1966. Other requests shall be referred to British Embassy, 3100 Massachusetts Avenue, NW, Washington, DC 20008.
AUTHORITY
DSTL, WO 404/16, 15 Dec 2008; DSTL, WO 404/16, 15 Dec 2008

ARMY PERSONNEL RESEARCH ESTABLISHMENT

REPORT No. 6/66

Control-Display Relationships in the Simulated ET 316 System

APRIL
1966

~~ARMY PERSONNEL RESEARCH ESTABLISHMENT~~

[redacted] 6/66

14 APRE-

7 ~~CONTROL-DISPLAY RELATIONSHIPS IN~~
~~THE SIMULATED BT 316 SYSTEM~~ EG-MHA7 5

~~by~~

8

10 L.R. Speight.

11 Apr 66 5

12 10 p.

Study: R20

Sponsor: DAEP

86/Research/1508

Approved Leonard W. Cronkite

Director

(040 630) CBSK

APRE REPORT NO. 6/66

CONTROL-DISPLAY RELATIONSHIPS IN THE SIMULATED ET 316 SYSTEM

by

L.R. Speight

SUMMARY

The visual display of the ET 316 tracking head lies in a near-vertical plane, but the joystick is mounted in the horizontal plane. Although the correspondence between "left" and "right" for both joystick and display is clear, opinion is sharply divided over the correspondence between "towards" and "away from" the operator for the joystick and "up" and "down" for the display. In view of this basic divergence of opinion it was decided to try and establish the relationship which seemed most natural for the majority of those who would eventually be called upon to operate ET 316.

One hundred and twenty eight personnel from 34 LAD Regt RA took part in the investigation. In a much simplified version of the ET 316 tracking head, operators were presented with slides of target aircraft and central crosswires, and were asked to make the joystick movement they thought appropriate to move the crosswires to the target. Although many operators (both with and without FCE 7 experience) moved the joystick towards them to raise the crosswires when targets were displaced only in the vertical dimension, only a few with FCE 7 experience used this "pull-to-raise" response when targets were diagonally displaced, and none without experience did so. The evidence suggests that a movement of the joystick away from the operator to raise the crosswires is in some sense the more natural of the two alternatives, and it is recommended that, if the control-display relationship for ET 316 must be fixed, this is the convention that should be adopted.

C O N T E N T S

	Paragraph	Page
INTRODUCTION		1
Background	1	1
Aim	5	2
METHOD		
Subjects	6	2
Equipment	7	3
Procedure	10	4
RESULTS	15	5
COMMENT	17	7
CONCLUSIONS	19	7
RECOMMENDATION	20	7
ACKNOWLEDGEMENT		8
REFERENCES		8
ANNEX: Statistical Analysis		9

CONTROL-DISPLAY RELATIONSHIPS IN THE SIMULATED ET 316 SYSTEM

by

L.R. Speight

INTRODUCTION

Background

1. The visual display of the ET 316 tracking head lies in a near-vertical plane but, for ease of tracking, the joystick is mounted in the horizontal plane. This gives rise to a genuine ambiguity. The correspondence between "left" and "right" for both joystick and display is clear, but opinion is sharply divided over the correspondence between "towards" and "away from" the operator for the joystick and "up" and "down" for the display. Many say that the operator should pull the joystick towards him to raise the cross-wires, and point to the analogy of flying an aircraft, or to raising a gun barrel. Others say that this reaction is unnatural. They point to such facts as that "up" on a picture in a book is that part of the book away from the observer. Those experts who have investigated this kind of problem (see, for example the summary given by Loveless(2)) agree that there seems to be no clear-cut expectation in the general population for one relationship to hold rather than another, although this may not be so for particular occupational groups.

2. It is unfortunate that there should be such strong disagreement on a matter which is so fundamental to tracking. Although to the uninitiated the point may seem trivial, few who have attempted to master a tracking task would feel disposed to agree. It is true that in one study of different control-display relationships(1) it did not prove possible to discriminate between them in terms of tracking accuracy. Nevertheless, most have reported a tendency to make infrequent, but serious, lapses when forced to track with a sense they regard as unnatural, and even when not under stress, claim that the task requires much more concentration. It is as if one portion of the mind must continually stay alert to remind oneself of the correct relationship. It has also been established beyond doubt that transferring from one relationship to another causes a complete disruption of skill, and re-learning in these circumstances is a far more lengthy and difficult process than was learning the skill in the first place.

3. In view of the basic divergence of opinions, it seemed that the most satisfactory course would be to try and establish the relationship which seemed most natural for the majority of those who would eventually be called upon to operate ET 316. To identify the correct population would seem to be essential, as people's past experience will almost certainly affect their present reactions. At the same time, a simple poll of opinions would seem to be inadequate. Not

only are many people unsure when questioned, but there is often a discrepancy between what people say and what they actually do.

4. It was because of these considerations that the investigation described in this report was carried out. It was assumed that, so far as the Army is concerned, FCE 7 operators and trackers (i.e., those trained only in the engagement aspects of FCE 7) will be converted to ET 316 when the latter comes into service, together with some (particularly replacements) who have had no such experience. Accordingly, one sample of FCE 7 operators and one with no FCE 7 experience acted as experimental subjects. They were asked to carry out certain basic actions with a very simplified simulation of the ET 316 tracking head.

Aim

5. To investigate the natural control-display response tendencies of a sample of potential ET 316 operators in a simulation of the ET 316 tracking system.

METHOD

Subjects

6. The investigation was carried out at Hilden, with personnel of 34 LAD Regiment RA. All those with FCE 7 laying experience took part, less a very small number absent on leave, courses, etc. A sample of personnel with no FCE 7 experience also participated. While the qualification for inclusion in Sample 1 is quite clear-cut, it is more difficult to define adequate criteria for inclusion in Sample 2. It was thought that at least two members per ET 316 detachment would have to be drivers, and that present gun numbers would in many cases be converted to ET 316, and so these were obvious candidates for inclusion. Apart from this, the aim was to include a fairly wide selection of Army trades. It was hoped that previous tracking experience would be the main determinant of expected control-display relationships, and that otherwise different sections of a Light Air Defence Regiment population would vary but little in this respect. It should be noted in this context that seventeen in Sample 2 had had laying experience with the L 40/70 gun. Details of rank and trade are given in Tables I and II.

TABLE I

Sample composition by ranks

Rank	FCE operators (Sample 1)	No FCE experience (Sample 2)
WO II		1
S/Sgt.	8	
Sgt.	2	2
Bdr.	9	5
L/Bdr.	12	13
Gnr.	27	49
Total	58	70

TABLE II

Sample composition by trade or function

Trade or function	FCE operators (Sample 1)	No FCE experience (Sample 2)
TSM		1
Detachment Cdr.	8	
" 2 i/c	2	1
Radar Op. B II	7	3
" " B III	6	
FCE Op. B II	4	
" " B III	18	
Driver/Op.	2	6
Driver	1	14
Gun No.	10	20
Clerk		10
Signaller		4
Tech. Asst. RA		1
Radio Tech.		1
T/Storeman		1
Storeman		1
G.D.		7
Total	58	70

Equipment

7. The equipment was constructed to reproduce the essential dimensions of the ET 316 tracking head. These were considered to be: the horizontal distance from the eyepiece to the joystick ($15\frac{1}{2}$"); the height of the eyepiece from the surface of the arm-rest (10"); and the angle of inclination of the eyepiece from the horizontal (30^{0}). In addition, by choice of seating, the vertical distance between the surface of the seat and that of the arm-rest was adjusted to approximately the expected value (16").

8. In essence, the equipment consisted of a large box, approximately 19" square, with the side facing the operator open. Three and a quarter inches from the floor level was a shelf (representing the arm-rest), at the far end of which, $14\frac{1}{2}$" from the front, was positioned a miniature joystick. The joystick was sprung, both because the instructions implied to each operator that he had a stable central reference point, and to act as a compromise between a free-moving and a pressure joystick, either of which could be used in ET 316. The output of this joystick was fed by a lead to an external pair of meters, on which the deflection in the "fore-and-aft" and "left-right" dimensions could be monitored. Four and a half inches from the front of the shelf previously mentioned a wooden spacer, 4" wide, stretched from floor to ceiling, to simulate the central support pylon of the genuine tracking head.

9. On top of the basic box structure of the equipment, and in place of the binocular eyepiece, was fixed a Sterolist stereoscopic slide viewer. The internal 12 volt bulb was connected in series with a timing unit, so that slides could be illuminated for a set period selected by the experimenter. A series of eight experimental colour slides were produced, each of which showed a central pair of cross-wires, a sky background, and a target aircraft (all of which were

approachers, although not necessarily head-on). These slides were produced from photographs of a model Fiat G 91 strike aircraft against a special sky wallpaper background, the same view being presented to each eye. Although each photograph was extremely realistic in appearance, no attempt was made to reproduce the full ET 316 field of view or to depict an aircraft at a particular range. Apart from the eight experimental slides, one slide of a dead-central target was produced for introductory purposes and to allow each subject to adjust the focus and eyepiece width. Table III gives details of the slides used.

TABLE III

Target slide details

Slide No.	Direction of displacement	Target aspect
Intro.	Central	Head-on
1	Right	Right crosser, level flight
2	Left	Left " " "
3	Up	Dead ahead, shallow climb
4	Down	" " , " "
5	Up-right	Right crosser, " "
6	Down-right	" " , " dive
7	Up-left	Left " , " "
8	Down-left	" " , " climb

Procedure

10. Before starting, each subject was told that he was about to take part in a short investigation which would affect the design of future tracking equipment. It was pointed out that aircraft targets were becoming more and more difficult to track and that to obtain good performance, it was necessary to pay attention to aspects of the task which, on the face of it, might seem trivial, but which were in fact of fundamental importance. The subject was then shown a schematic illustration of the ET 316 tracking head, and the joystick, optical sight, and binocular eyepiece were pointed out. A large black-and-white photograph, with central crosswires and target in the upper right quadrant, was next shown as an example of the field-of-view an operator could expect. (Great care was taken to expose this photo only in the near-vertical plane, to avoid translating this vertical configuration to a particular horizontal one in front of the subject's eyes.) He was told that it was the job of the operator to move the crosswires onto the target and hold it there, the movement "crosswires-to-target" and not "target-to-crosswires" being re-emphasised.

11. It was next explained to each subject that we were concerned with the possibility of bias with this tracking configuration: that is, whether people tended inadvertently to move the joystick in one direction when trying to move it in another, or, when targets were displaced at an angle, whether people could judge the right direction to move the joystick. The experimental tracking station was next indicated, and it was explained that in all important respects it reproduced the dimensions of the apparatus which they had just seen illustrated. It was explained that a number of slides had been prepared, giving similar target views to the one they had been shown, and that the precise angle of each target from the centre of the crosswires was known. The subject was told that he would be presented with this series of slides, one at a time. At each presentation the experimenter would press a

button, illuminating the target for a few moments. When this happened, the subject would be required to move his joystick in the direction he thought appropriate to move the crosswires to the target. At this point it was emphasised that in this case the crosswires would not actually move: if they did, the subject could correct his reaction in the light of what he saw, and that it was his first reaction with which we were concerned. The instruction that the subject should move his joystick in the direction he thought appropriate to move the crosswires to the target was then repeated.

12. If a subject inquired about the correct control-display relationship in the vertical dimension, he was told to respond in the way that felt most natural to him, and that his particular preference could be allowed for in the analysis. In fact, during the whole trial only two people raised this query, one before any targets were presented and one after the series was complete.

13. After the introductory talk each subject viewed the demonstration slide with continuous illumination and was allowed to adjust the focus and eyepiece spacing to his taste. The illuminating bulb was then switched off; Slide 1 was placed in position; the timed illumination button pressed (lighting the bulb for 2.5 sec); the direction of joystick deflection noted, and so on to complete the series. Half the men had the slides presented in numerical order, as shown in Table III, and half in the same order, but with Slides 3 and 4 moved to the end of the series. (Originally, it was planned to present all slides in the first of these orders. However, a pilot study with 15 men with no previous tracking experience suggested that people often differed in the reactions to vertically- and to diagonally-displaced targets, and so it was decided to check on the effect of presentation order.)

14. The aim of the slightly misleading instructions outlined above was to draw primary attention away from the topic of control-display sense, and to reveal the subject's unstudied reactions. Also, it had been found from experience that the topic was contentious, frequently provoking surprisingly emotional argument. If stress had been placed on the true topic of enquiry, it was feared that subjects might come to the experiment biased from previously heard discussions. In fact, the subjects without exception reacted favourably to the instructions, and co-operated fully. Very many expressed interest in the experiment.

RESULTS

15. The reactions of all subjects to target Slides 1 and 2 were entirely consistent: without exception, they moved their joystick to the right if the target was to the right, and to the left if the target was to the left. To classify the reactions of the subjects to the other six slides, the following categories of response were defined:

For Slides 3 and 4:

A joystick moved away from operator for target above, and towards operator for target below ("push-to- raise" crosswires),

B the reverse of A ("pull-to-raise" crosswires),

and for Slides 5-8 (diagonally displaced targets):

C as for A, plus normal horizontal reaction,

D as for B, plus normal horizontal reaction,

E inconsistent (i.e. "to-from" or "left-right" responses used inconsistently within this sub-series of four slides, or as for A or B above but with horizontal relationship reversed).

It will be noted that there was no need to devise an "inconsistent" category for Slides 3 and 4. Using these categories, the results are summarized in Table IV. They are shown in this way to bring out the relationship between response to targets displaced in one plane only, and to targets diagonally displaced. Presentation order (a) refers to the target slides being administered in numerical order, and (b) to the same order, but with Slides 3 and 4 moved to the end of the series (see para. 13).

TABLE IV

Summary of responses

Sample	Presentation order	Response					
		A	B	C	D	E	Total
		(Slides 3 & 4)		(Slides 5-8)			
FCE 7 operators	a	10	-	10	0	0	
		-	19	9	3	7	
				19	3	7	29
	b	16	-	15	0	1	
		-	13	3	4	6	
				18	4	7	29
	Total	26	32	37	7	14	58
No FCE 7 experience	a	20	-	20	0	0	
		-	15	9	0	6	
				29	0	6	35
	b	30	-	30	0	0	
		-	5	2	0	3	
				32	0	3	35
	Total	50	20	61	0	9	70

16. The more striking points to emerge from these figures are:

(a) The response tendencies of those with and those without FCE 7 experience differ significantly.

(b) With only one exception, all those who gave reaction A ("push-to-raise") for vertically displaced targets remained consistent with this reaction for targets in the four quadrants.

(c) A fair proportion giving reaction B ("pull-to-raise") converted to the opposite sense in the vertical plane when faced with diagonally displaced targets, and a fair proportion reacted inconsistently. Very few

consistently maintained the "pull-to-raise" reaction when targets were not actually on the vertical crosswire.

(d) A significantly higher proportion of operators gave response A ("push-to-raise") to Slides 3 and 4 when they were administered at the end of the presentation sequence. On the other hand, order of presentation had no effect on the reaction to diagonally displaced targets.

Tests of significance in support of these statements are given in the Annex.

COMMENT

17. Before commenting on the results, one point should be emphasised. This study was aimed at ET 316, and this determined the configuration which was used and the population which was sampled. To extrapolate the results to other different conditions may be unwarranted.

18. For targets displaced only in the vertical dimension, it seems that a fair proportion of the population of a Light Air Defence Regiment (even those without FCE 7 experience) expect a movement of the joystick towards the operator to raise the crosswires. This could be because they regarded the operation as analogous to raising a gun barrel or flying an aeroplane. But the results of this study suggest that it is unfortunate that this should be so. Very few indeed seem to find this the "natural" relationship when targets are displaced in both the horizontal and the vertical dimensions simultaneously. Indeed the FCE 7 operators, who have presumably had their reactions affected by training, are far less consistent than the others when faced with targets in the four quadrants, in spite of (or because of) their practice in tracking. It will be recalled, too, that progression from diagonally- to vertically-displaced targets had a significant effect on the response to these latter, more people then employing the "push-to-raise" response. Progression in the other direction had no effect, and it is obviously easier to eradicate the "pull-to-raise" response than its opposite. The general impression gained from this study is that the "push-to-raise" response is in some sense the more natural one, which has been modified to some extent by the knowledge that the opposite convention is employed in many modern mechanical designs.

CONCLUSIONS

19. It is concluded that:

(a) For targets displaced only in the vertical plane there was a fairly widespread expectation among potential ET 316 operators that the joystick should be pulled towards the operator to raise the crosswires. This expectation was more widespread among those with FCE 7 experience (45%-66%) than among those without (14%-43%), and was influenced by the immediately preceding target history.

(b) For targets displaced in one of the four quadrants only a small proportion (12%) of those with FCE 7 experience used the "pull-to-raise" response, and

none without experience did so. For both classes of operator, the majority consistently chose the opposite relationship under these conditions.

(c) The evidence suggests that a movement of the joystick away from the operator to raise the crosswires is in some sense the more natural of the two alternatives.

RECOMMENDATION

20. It is recommended that, if the control-display relationship must be fixed for ET 316, the convention to be adopted should be: a movement of the joystick to the left moves the crosswires to the left (and vice versa); and a movement of the joystick away from the operator moves the crosswires up (and vice versa).

ACKNOWLEDGEMENT

The author would like to express his thanks to 34 LAD Regiment RA, for their help and co-operation in this investigation.

REFERENCES

1. Andreas, B.G., Finck, A., Green, R.F., Smith, S., and Spragg, S.D.S. Two-dimensional compensatory tracking performance as a function of control-display movement relationships, position vs. velocity relationship, and miniature vs. large stick control. J. Psychol (48) 237-246, 1959.

2. Loveless, N.E. Direction-of-motion stereotypes: a review. Ergonomics (5) 357-383, 1962.

ANNEX

Statistical Analysis

A.1. The data for categories of response have been treated by Lancaster's method for the partition of chi-square(A.1) A summary of reactions to Slides 3 and 4 (targets displaced only in the vertical plane) is given in Table A I below, and the resultant partition of chi-square in Table A.II.

TABLE A.I

Data Summary for Slides 3 and 4

Sample	Presentation order	Response A	Response B	Total
FCE 7 operators	a	10	19	29
	b	16	13	29
		26	32	58
No FCE 7 experience	a	20	15	35
	b	30	5	35
		50	20	70

TABLE A.II

Partition of chi-square for Slides 3 and 4

Source	χ^2	df	Significance
Response x FCE experience	9.305	1	$p < .005$
Response x presentation order	8.292	1	$p < .005$
Response x FCE experience x presentation order	0.139	1	N.S.
Total	17.736	3	

A.2. For Slides 5-8 (targets in the four quadrants) the relevant tables are given below. Response categories D and E have been pooled to give sufficiently large expectations in each cell.

TABLE A.III

Data summary for Slides 5-8

Sample	Presentation order	Response C	Response D + E	Total
FCE 7 operators	a	19	10	29
	b	18	11	29
		37	21	58
No FCE 7 experience	a	29	6	35
	b	32	3	35
		61	9	70

TABLE A.IV

Partition of chi-square for Slides 5-8

Source	χ^2	df	Significance
Response x FCE experience	9.637	1	$p < .005$
Response x presentation order	0.174	1	N.S.
Response x FCE experience x presentation order	0.639	1	N.S.
Total	10.450	3	

REFERENCE

A.1. Lancaster, H.O. Complex contingency tables treated by the partition of χ^2 J. Roy. Stat. Soc., Ser. B (13) 242-249, 1951.

DISTRIBUTION

	Number of Copies
Ministry of Defence, Army Department	
DCS(Army	1
DAOSR	1
AD/AOSR(B)	3
DAEP	1
AEP 6	1
DG of Arty	1
Arty 4	1
DRA	1
Commandant, S of A, Manorbier	1
AWSG	1
HQ BAOR	2
HQ 1(BR) Corps (including 1 for ORLO)	2
HQ FARELF (G (OR & A))	2
Ministry of Defence, Central Staffs	
DCSA(S)	1
ACSA(P) (Attn: Def.Sc.11)	1
Ministry of Defence, Navy Department	
SP(N)	1
Ministry of Defence, Air Force Department	
DDOR 6 (Attn: OR 18)	2
ACS(P)	1
Institute of Aviation Medicine	1
Ministry of Aviation	
DGW(M)	1
RRE (1 each for Lt.Col. D. Rennie, J.B. Diamond, and J.S. Bickerdike; 2 for L.A. Nicholls)	5
Medical Research Council	
RNPRC	1
APRC	1
FPRC	1
Applied Psychology Research Unit, Cambridge	1
Canadian Army Standardisation Representative, UK	6
Senior US Army Standardisation Representative, UK	12
Senior Australian Army Standardisation Representative, UK	4
Human Engineering Group, Aeronautical Research Laboratory, Australia	1
British Aircraft Corporation, Stevenage (1 each for G.E. King, R.M. Taunton, D. Thomas)	3
British Aircraft Corporation Bristol (Attention: I. McFarlane)	1

[dstl]

Information Centre
Knowledge Services
[dstl] Porton Down
Salisbury
Wilts
SP4 0JQ
22060-6218
Tel: 01980-613753
Fax 01980-613970

Defense Technical Information Center (DTIC)
8725 John J. Kingman Road, Suit 0944
Fort Belvoir, VA 22060-6218
U.S.A.

AD#: AD 396801

Date of Search: 15 December 2008

Record Summary: WO 404/16
Title: Control-display relationships in the simulated ET 316 system
Former reference (Department): REPORT 6/66
Held by The National Archives, Kew

This document is now available at the National Archives, Kew, Surrey, United Kingdom.

DTIC has checked the National Archives Catalogue website (http://www.nationalarchives.gov.uk) and found the document is available and releasable to the public.

Access to UK public records is governed by statute, namely the Public Records Act, 1958, and the Public Records Act, 1967.
The document has been released under the 30 year rule.
(The vast majority of records selected for permanent preservation are made available to the public when they are 30 years old. This is commonly referred to as the 30 year rule and was established by the Public Records Act of 1967).

This document may be treated as UNLIMITED.